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Treating Construction Soils to Infiltrate Stormwater:

Bay Area Field Trial

Summary: Areas to receive permanent erosion control planting became highly disturbed and compacted in the course of bridge construction work at Highway 80 and Hilltop Drive, Richmond, in the S.F. Bay Area. Findings from the Soil Resource Evaluation (SRE II) research funded by Caltrans demonstrate methods to improve erosion resistance and planting cover in highly disturbed soils. Therefore, the basic treatments outlined by the SRE research were added to the Hilltop bridge construction work prior to planting. Despite both high intensity and long duration storm events over the winter of 2010, the treated areas of the project site remained erosion resistant, allowing the seeded and container plantings to root in. This field trial adds to positive results reported by others. It is recommended that: the Soil Resource treatments be fitted to the different climates, plants, and soil substrates found in Caltrans districts to enable implementation as a standard design and construction stormwater practice.

Project: Hilltop Dr./I-80 bridge replacement (EA 04-1A2504) with highway planting included.

Construction of replacement bridge on Hilltop Drive in Richmond: associated soil disturbance and compaction

Conditions and Agreements with Contractor

At the beginning of the bridge construction project the Contractor asked to park heavy construction equipment within the Caltrans Right of Way (ROW). The equipment yard would be located on flat soils, however areas were to be planted and seeded following completion of bridge work. Under the contract Special Provisions, the Resident Engineer had the option of allowing or disallowing the Contractor to park equipment in the ROW.

The R.E. concurred with Landscape Construction's recommendation that, as a condition of an equipment yard on the Caltrans ROW, soils in this area would be ripped at the end of bridge construction as part of the contract (i.e. not paid extra work) to restore pre-construction soil conditions.

Steps to Restoring Soil Water Infiltration and Deep Rooting

In 2008, the Caltrans Environmental Analysis and Landscape Architecture Program released research by the UC Davis Soil and Revegetation Lab under Dr. Vic Claassen (1) on soil-based methods for regenerating plant cover in highly disturbed and compacted soils. The resulting Soil Resource methods and treatments from the research are germane to the soils issues at Hilltop/I-80. At completion of the bridge and roadway construction work it was difficult to even drive a pick into the compacted planting area soils. Follow up planting is required to provide desirable and permanent erosion control vegetation cover. However, long term planting success would be compromised by a highly restricted rooting depth and loss of soil moisture to surface runoff. Therefore, in consultation and collaboration with the Resident Engineer, Design Landscape Architect, and Contractor, the Soil Resource method and treatments described below were added prior to planting work.

1. Borrowing "what works" from a Soil-Plant Reference Site

The first step recommended in the Soil Resource method is to locate a functioning soil-plant reference site to borrow some of "what works" and incorporate it into the planting site (1)(4). The landscape plan for the site specified native perennial grass seeding and ornamental and native container tree and shrub plantings. An remnant native perennial Purple Needle Grass (Nassella pulchra) prairie and native shrubs are located in the ROW immediatedly above the construction site. This nearby native grassland "soil-plant system" provided a good reference site because aspect, slope, climate, and geology were all similar. The reference site also supports the same native perennial grass species, Nassella pulchra, planned for seeding onto the construction site for erosion control and landscaping purposes.

Nearby stand of native Purple Needle Grass and shrubs

The soil in the functioning native grass prairie had visibly less compaction, higher soil aggregation, and higher organic matter than soil at the construction site. I requested a Construction Lab nuclear probe test of both the grassland reference site and the equipment yard to verify the difference in compaction level. The nuclear probe results indicated that the the nearby reference native grassland was approximately 81% of maximum compaction for that native soil. In comparison, the test results for the construction area soils were at 99% of maximum compaction for that sandy clay substrate. Any previous soil aggregation in the construction area had been lost due to excavation, filling, and equipment traffic. The prevalence of light, mineral soils suggested that soil organic matter was very limited.

Therefore, very basic comparisons between the reference site and construction site indicated that the construction area soils would need increased soil pore space and added organic matter to enable stormwater infiltration and deep rooting.

2a. Former Equipment Storage Yard Ripped to 3' (1 meter)

The nuclear probe test essentially verified that excessive compaction remained on the construction site. Per agreement, the Contractor ripped the former equipment storage area with a Cat D-8 with a 3' ripping shank (the equipment yard area was about one-quarter of the entire bare soil area to be seeded and container planted).

Equipment for Ripping to 1 meter/3' heavily compacted equipment storage area

2b. Rip Remainder of Site to 1.5' (.5 meter)

Following the initial deep ripping of the former equipment storage yard, we determined that additional ripping was needed for the remainder of the site. It had also become highly compacted from heavy equipment driving on these areas during the previous wet season.

Slots ripped into compacted surface

The R.E. had the contractor rip the entire 1.3 acre circle onramp, along with a .6 acre westbound onramp plateau. A D-6 sized tractor with a 1.5' shank was used. I requested the ripping be done on contour and at a slight downward angle to direct infiltrated stormwater from the wetter, cut slope areas to the dryer, lower gradient areas (based on earlier observations of wet areas this winter). As described in the UC Davis research, the ripping left slots in the soil for water infiltration and future deep rooting, while maintaining geotechnical stability with a stepped (non-planar) interface between the tilled substrate and the underlying geological layers.

Of note, the D-6 sized tractor would frequently skid in place while attempting to rip the soil surface to 1.5'. It would then have to lift the ripping shanks and restart the ripping. I later checked ripping depth along a 50' transect. The tractor had sliced a shallower 4"-12" ripping depth in several areas.

3. Compost/Compost Overs Spread and Cultivated

Project site ripped and then tilled after application of course compost organics ("compost overs")

Following ripping, approximately 1.5" of compost and "compost overs" were spread over the site ("compost overs" were 1"-3" in length). Since the contract work for seeding already included "Cultivation", the organics were spread prior to cultivation so they could be incorporated into the top 4"-6" of soil. Cultivation was done by a tractor-mounted tiller that more thoroughly incorporated the organics into the soil than the ripping alone would have.

The contract also required *scarification* of the soil prior to applying the perennial grass seed. The Contractor used the same small tractor to scarify the soil surface to a shallower depth (4") just prior to seeding. A surface crust had developed from an earlier rain so scarification was beneficial for loosening the seeding bed surface and eliminating early germinating annual weeds.

In sum, a compost amendment was added to the Landscape Contractor's cultivation and scarification contract work. The result was a good mixing of the compost amendments into the top 4-6" of the soil surface, along with an unknown incorporation of compost into the deeper ripped slots.

Considerations

There are several obvious questions that come up when adding ripping and amendment to a construction project. Below is a brief discussion of the major considerations:

- Costs - each step above took about a day with operator and the above-noted equipment.
- No underground utilities were affected. We determined that electrical service and irrigation would be within the first 10' of the curb edge, so only shallow ripping was done on the site perimeter.
- Excessive rock or concrete scrap would not likely be pulled up during the ripping since the circle onramp had been a planting area before. Concrete pieces >6" across pulled up from tractor ripping were collected and removed as extra work.
- Two steep road cut slopes on the project site were left alone (However, the SRE Technical Memorandum (1) describes three field trials where slope-appropriate soil treatment methods were incorporated into 2:1 (h:v) slopes and to effectively increase erosion resistance and permanent vegetation cover.)

Performance to Date – High Volume Storm event

On Tuesday, October 13, 2009, an early fall, 45 year storm event pelted the site with **5”** of rainfall over an 8 hour period. Some of the stormwater benefits of improved stormwater infiltration into soils were demonstrated during this high volume storm.

On a short side slope that had remained compacted from construction, sediment movement and minor rilling was evident after only **10’ of slope length** (although surface erosion control had been planned, it was not applied in time for the storm. The minor amount of sediment was subsequently cleared from the roadway). The slope has only a 15% grade. The side slope illustrated how the entire site would have likely responded if left in a similar compacted, unamended condition. (Note: Surface erosion is increased by low soil infiltration. At another project site, erosion patterns were observed on a similarly compacted road edge covered with a 4” compost blanket).

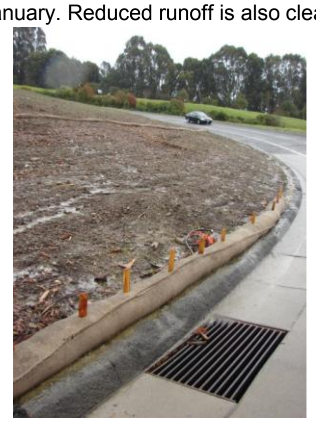
Untreated side slope (above). Treated slope (below) during one day 5” storm

The much larger 1.3 acre circle onramp was treated primarily with ripping and amending as described earlier. The soil surface had just been seeded with the native perennial grass. Two fiber rolls were installed to slow any surface runoff.

Unlike the sediment loss after only 10’ feet in the above compacted area, the soils stayed in place with no rilling over **140’ of slope length**. At a steeper 30% gradient sections there were 5 minor rills (note: would the storm been fully infiltrated if the ripping was consistent to the planned depth?) Also, of interest, when rainfall exceeded the infiltration rate into the soil, the compost overs at the surface formed, in effect, hundreds of small fiber rolls that contained any dislodged soil particles, reduced the effective slope length, and slowed minor runoff.

Longer Duration Storm Event

Treated slope during the fourth day of a 6” storm in January. Reduced runoff is also clear water



In January, 2010, 6” of rain fell over 4 days from Monday, January 18 to Thursday, January 21. I visited the site at the end of the storm and found no rilling or gullying on the decompacted-amended areas. The permanent erosion control grasses had germinated, but were only 1” tall. The soils were likely saturated, and a minor amount of storm water was being released from the toe of slope. The reduced runoff was clear.

Initial Field Trial Results – A Cost-effective, permanent stormwater pollution prevention measure

This field trial applies the scientific investigation and subsequent slope experiments of the UC Davis SRE II research to a degraded slope soil using existing construction equipment, materials, and personnel. The Soil Resource research could be applied with confidence because it is backed by scientific investigation and explanation, consistent with current geotechnical literature (2)(3), and has undergone tests in a variety of situations. The Soil Resource research findings have been used to repair 2:1 (h:v) highway slopes that had failed under conventional slope treatments and to stabilize and revegetate decomposed granite Sierra slopes in District 3 (Monica Finn and David Moffatt) (3).

Soil treatments can be designed to manage different intensity storms across the State. However, to be used as a standard stormwater and sediment control practice, designers and engineers will need a procedural reference fitted to the State's differing soil types, climate patterns, and planting conditions. To become part of the toolbox for stabilizing steeper slope surfaces, technical involvement and buy in from geotechnical engineers will be needed. Some more monitored field site trials would certainly aid state-wide adoption.

As a standard stormwater and construction practice, soil management has multiple payoffs. When soil management is incorporated into detention and drainage system design, a larger portion of stormwater can be designed to infiltrate into the soil profile, thus reducing constructed infrastructure size and lifecycle costs. Also, the Soil and Revegetation Lab research shows that when soil water is retained, permanent erosion control landscaping can draw on soil water during dry months, significantly reducing water bills and irrigation system maintenance demands. (1). Soil Resource management is a sensible, practical, and effective stormwater design and construction practice capable of returning benefits over a long term.

1. For Soil Resource Evaluation research, see Caltrans Landscape Architecture: http://www.dot.ca.gov/hq/LandArch/research/soils.htm, including: Soil Resource Evaluation II (2008) Soils Resource Evaluation Pilot Study Construction Report (2008), Providing Adequate Moisture for Plant Establishment under Reduced Irrigation (2008)
2. Goldsmith, W., Silva, M., and Fischenich, C. (2001). "Determining optimal degree of soil compaction for balancing mechanical stability and plant growth capacity," ERDC TN-EMRRP-SR-26), U.S. Army Engineer Research and Development Center,Vicksburg, MS. http://el.erdc.usace.army.mil/elpubs/pdf/sr26.pdf
3. Gray, Donald H., former Civil Engineering Professor, University of Michigan, and Monica Finn, Caltrans Biologist "Optimizing Soil Compaction" webinar by, (July 2009) http://www.dot.ca.gov/hq/LandArch/webinars/index.htm
4. Claassen, Vic "Soil Structure and Soil Health" webinar (May 2009), http://www.dot.ca.gov/hq/LandArch/webinars/index.htm

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